Scientific Value of a Saturn Atmospheric Probe Mission. A. A. Simon-Miller[1], J. I. Lunine[2], S. K. Atreya[3], T. R. Spilker[4], A. Coustenis[5], D. H. Atkinson[4,6], A. Colaprete[7], and K. Reh[4], [1]NASA Goddard Space Flight Center, [2]Cornell University [3]University of Michigan, [4]NASA Jet Propulsion Lab, [5]LESIA, Observatoire de Paris-Meudon, [6]University of Idaho, [7]NASA Ames Research Center.

Introduction: Atmospheric entry probe missions to the giant planets can uniquely discriminate between competing theories of solar system formation and the origin and evolution of the giant planets and their atmospheres. This provides for important comparative studies of the gas and ice giants, and to provide a laboratory for studying the atmospheric chemistries, dynamics, and interiors of all the planets including Earth. The giant planets also represent a valuable link to extrasolar planetary systems. As outlined in the recent Planetary Decadal Survey, a Saturn Probe mission - with a shallow probe - ranks as a high priority for a New Frontiers class mission [1].

Why Shallow Atmospheric Probes?: We define a shallow probe as one that descends through 5 to 10 bars of atmospheric pressure. For Saturn, a carrier spacecraft powered by Advanced Stirling Radioisotope Generators (ASRG) and an entry probe using carbon phenolic Thermal Protection System (TPS) technologies similar to those used by the Galileo Jupiter probe requires no new technology developments beyond NASA's funded ASRG completion task.

The atmospheric constituents needed to constrain theories of solar system formation and the origin and evolution of the giant planets can be accessed and sampled by shallow entry probes. Many of these important constituents are spectrally inactive or are beneath an optically thick overburden at useful wavelengths, and therefore are not accessible by remote sensing, such as from Cassini. A small, scientifically focused shallow entry probe mission can make the critical abundance measurements of key constituents, and can measure depth profiles of atmospheric structure and dynamics at a significantly higher vertical resolution than can be achieved by remote sensing techniques alone.

Completion of comparative study of Jupiter and Saturn: The Galileo mission began the detailed study of the solar system's two major gas giants by dropping an entry probe into Jupiter atmosphere and deploying an orbiter around Jupiter. Detailed gravitational and magnetic field measurements of Jupiter, along with a determination of the deep oxygen abundance will be made by the Juno mission in 2016-17. In the same period the Cassini Saturn Orbiter will begin a set of Juno-like orbits to make comparable measurements of Saturn. A Saturn atmospheric entry probe would complete the quartet of missions needed to comprehensively and comparatively study the two planets [2].

Science Achievable: Keeping the scientific mission highly focused with a minimal science payload enables an outer planet mission that fits within existing program budget caps while still addressing unique and critical science. Fundamental measurements made from a small and scientifically focused Saturn entry probe include abundances of the noble gases He, Ne, Ar, Kr, and Xe, abundances of key isotopic ratios $^{4}He/^{3}He$, D/H, $^{15}N/^{14}N$, $^{18}O/^{16}O$, and $^{13}C/^{12}C$, and detection of disequilibrium species such as CO, PH_3, AsH_3, and GeH_4. These are diagnostic of deeper internal processes and dynamics of the atmosphere along the probe descent path. Abundances of these key constituents, as well as carbon, which does not condense at Saturn, sulfur, which is expected to be well-mixed below the 4 to 5-bar ammonium hydrosulfide (NH_4SH) cloud, and gradients of nitrogen, below the NH_4SH cloud, and oxygen, in the upper layers of the water and water-ammonia solution cloud, can be measured by a shallow entry probe descending through 5 or 10 bars.

In addition, there are also possible savings in cost, mass, and capability that can be realized by utilizing state-of-the-art miniaturization and low power techniques, and reductions in TPS mass fraction. Although the aim would be to keep the mission focused and streamlined, with significant mass savings, and proper trajectory analysis, comes the ability to add a flyby of another body in the Saturn system or added science payload on the orbiter or probe. These further increase the science return of such a mission, but require careful analysis of science value vs. cost, risk, and complexity.

Summary: A shallow Saturn probe is capable of obtaining the key noble gas and isotopic abundances, plus vertical abundance profiles for other constituents, not accessible to an orbiter mission. In concert with the results from Galileo, Cassini, and Juno, these measurements are critical to enabling a full comparison of composition and dynamical processes on Jupiter and Saturn. A better understanding of the structure of the gas and ice giants in our solar system will ultimately aid future studies of exoplanets, as well.

References: [1] NRC Space Studies Board Planetary Decadal Survey, Visions and Voyages for Planetary Science in the Decade 2013-2022. [2] NRC Space Studies Board COMPLEX Report, A Strategy for Exploration of the Outer Planets: 1986-1996.